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RACK INSERTION END EFFECTOR (RIEE) GUIDANCE

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ABSTRACT

NASA-KSC has developed a mechanism to handle and insert Racks into the Space Station Logistic Modules. This mechanism consists of a Base with 3 motorized degrees of freedom, a 3 section motorized Boom that goes from 15 to 44 feet in length, and a Rack Insertion End Effector (RIEE) with 5 hand wheels for precise alignment.

During the 1993 NASA-ASEE Summer Faculty Fellowship Program at KSC, I designed an Active Vision (Camera) Arrangement and developed an algorithm to determine (1) the displacements required by the Boom for its initial positioning and (2) the rotations required at the five hand-wheels of the RIEE, for the insertion of the Rack, using the centroids of the Camera Images of the Location Targets in the Logistic Module.

Presently, during the summer of '94, I completed the preliminary design of an easily portable measuring instrument using encoders to obtain the 3-Dimensional Coordinates of Location Targets in the Logistic Module relative to the RIEE mechanism frame. The algorithm developed in '93 can use the output of this instrument also.

Simplification of the '93 work and suggestions for the future work are discussed.

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RACK INSERTION END-EFFECTOR (RIEE) GUIDANCE

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1. INTRODUCTION:

Towards an efficient guidance of the RACK INSERTION END-EFFECTOR (RIEE) Mechanism, a Spherical Coordinate Encoder Module (SCEM) has been designed to determine the X, Y & Z coordinates of the Rack Supports with respect to the Boom, by measuring the Spherical Coordinates of the Rack Supports relative to the Rack Interface Plate.

This work is in continuation of the '93 Summer work that resulted in the Conceptual Development of an Active Vision Alignment System (AVAS) to determine the above X, Y & Z coordinates, using a vision system attached to the Rack Interface Plate.

The X, Y & Z coordinates obtained as above, will become inputs to a program that determines the displacements required by Boom and the Handwheels of the RIEE to:

- 1) Align the RIEE relative to the Logistic Module to Prepare for Final insertion. and
- 2) Translate the Rack Rotation Axis and rotate the Rack about it for Final Insertion.

The following sections contain description of concepts, derivation of equations, the preliminary design details of SCEM and the alignment procedures for the RIEE.

2. THE RIEE MECHANISM

The RIEE is a space mechanism with 5 degrees of freedom. It has 12 links and 15 joints. It is used to align the axis of rotation of the Rack and perform the final insertion of the Rack into the Logistic Module. The Boom carrying the RIEE, has 4 degrees of freedom. Figures 1 & 2 show the RIEE in two positions as per drawing # 82K03931.

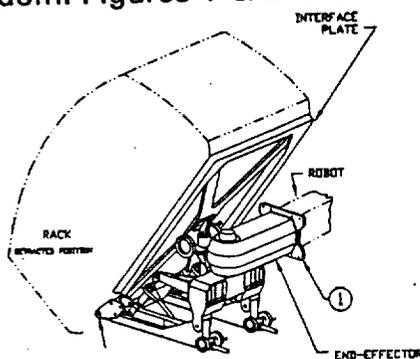


Figure 1. RIEE in Retracted Position

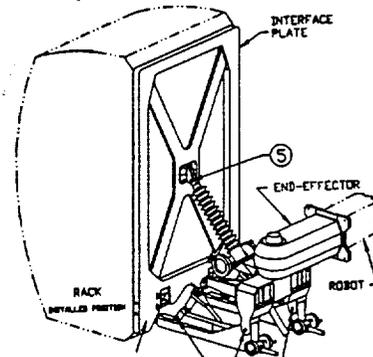


Figure 2. RIEE in Installed Position

3. DETERMINATION OF THE COORDINATES OF THE SUPPORTS IN THE FRAME OF SCEM.

To insert the rack we have to know the positions of the rack support points on the logistic module, shown as lower support points in Figure 3 below. In the following Analysis expressions are derived for the coordinates of the left and right support points by getting the spherical coordinates of the support points by scem. The figure shows typical relationship of a SCEM to a support in the yz plane of the boom coordinate system containing the RIEE. The RIEE mechanism has 2 end-effector points on the left and right sides shown by the letter E and top end-effector point P. Different views of this mechanism can be studied in the set of drawings # 89K03931. The points shown in the figure carry prefixes "R" for right and "L" for left in the discussion that follows.

RIEE MECHANISM SCHEMATIC

(Not to scale)

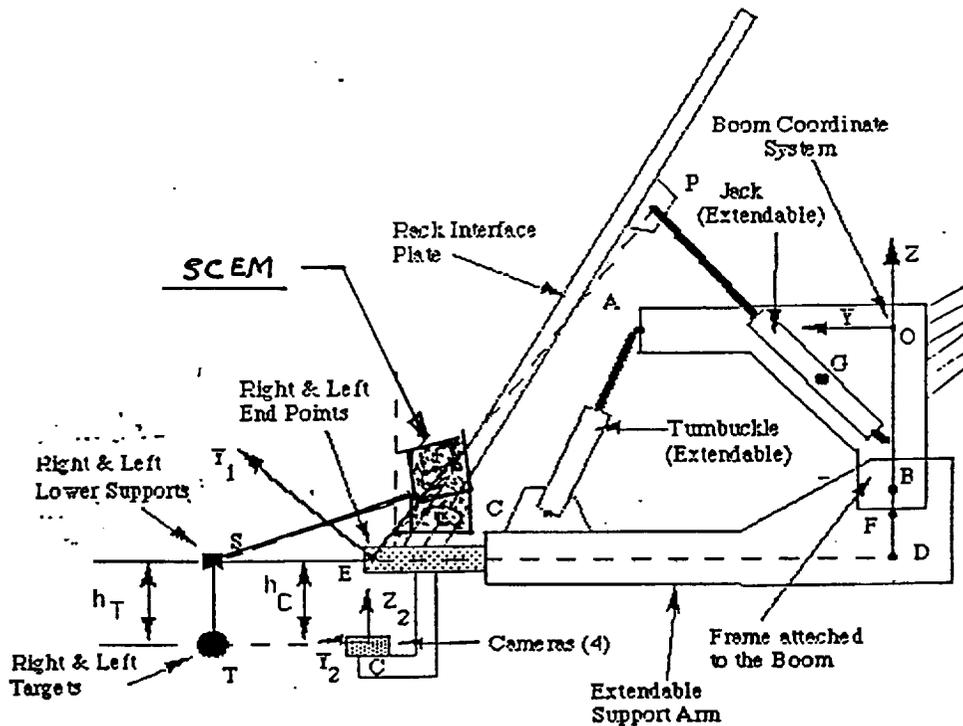


Figure 3

3.1 CONCEPT OF SCYM:

The concept of SCYM as shown in Figure 4 is provided by NASA Colleague Eduardo Lopez. It essentially contains a Wire or Tape Pool in an encasement attached to a mount with a shaft that can rotate on a rotating base. The rotating base has a shaft, whose axis is perpendicular to the shaft of the mount, rotating on a portable base. To each of the shafts of the rotating mount and the rotating base, a code wheel is attached. The encoders attached to the Rotating and the portable bases measure the rotation angles of the mount and the rotating base. The intersection of the two shaft axes form the origin of the SCYM coordinate system. The wire or tape length measured by a suitable encoder is the radial coordinate.

CONCEPT OF SCYM

Mike Jazdec & Eduardo Lopez del Castillo
NASA - KSC

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5/6/94
Eduardo Lopez del Castillo 5/6/94

this code wheel is attached to a roller that rotates as wire is deployed.
The wire will roll-up on a spring loaded reel (can't be seen on this figure).

- everything mounted on or above part labeled A can rotate about X-axis.
- everything mounted on or above part labeled B can rotate about Y-axis as well as X-axis

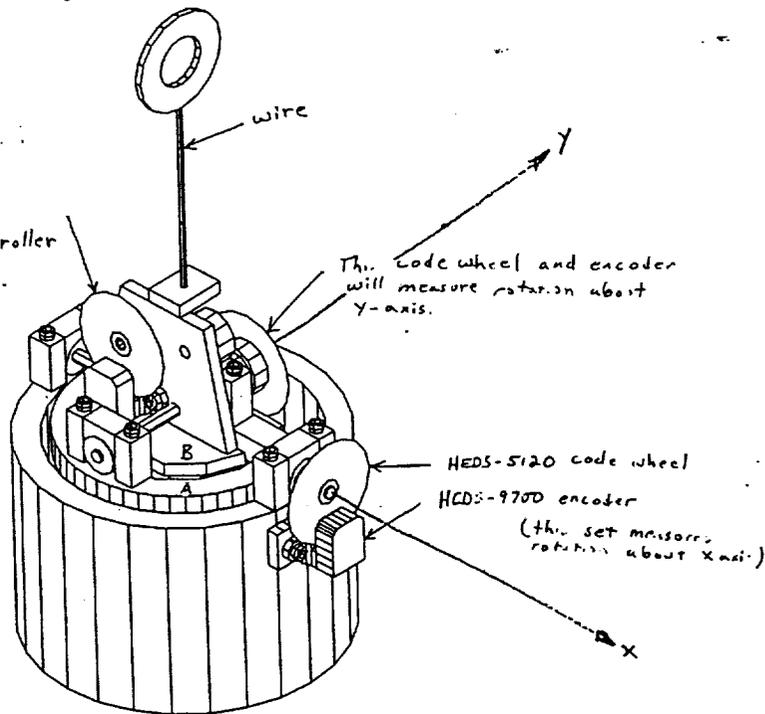


Figure 4

ORIGINAL PAGE IS
OF POOR QUALITY

3.2 DESIGN OF SCEM:

Figure 5 shows the assembly drawing of the SCEM. The major parts and the material employed are listed below. The SCEM is connected to a Computer.

| S. N. | Part | No. Off | Material/Part No. |
|-------|---------------|---------|--|
| 01 | Portable Base | 1 | Oil Impregnated Cast Nylon McMASTER 8664K24 (page 2487) |
| 02 | Rotating Base | 1 | Oil Impregnated Cast Nylon |
| 03 | Tape Mount | 1 | Lexan |
| 04 | Base Shaft | 1 | Aluminum |
| 05 | Mount Shaft | 1 | Aluminum |
| 06 | Cover | 2 | Lexan |
| 07 | Code wheel | 2 | HP-HEDG-6120 # U08 |
| 08 | Encoder | 2 | HP-HEDS-9000 Option U00 |
| 09 | Tape Encoder | 1 | NEWARK-87F6454-HOA709-001 |
| 10 | Tape | 1 | STANLEY-12ft tape |

The origin of the Spherical Coordinate System is at O, the intersection of the axes of the two rotating shafts. The angle of the tape Length is measured from the Z axis by the top encoder reading the Vertical code wheel. The angle from x axis, in the xy plane is measured by the bottom encoder reading the Horizontal Code wheel. The part drawings are not included here to conserve the space. They are submitted to NASA Colleague, Eduardo Lopez,

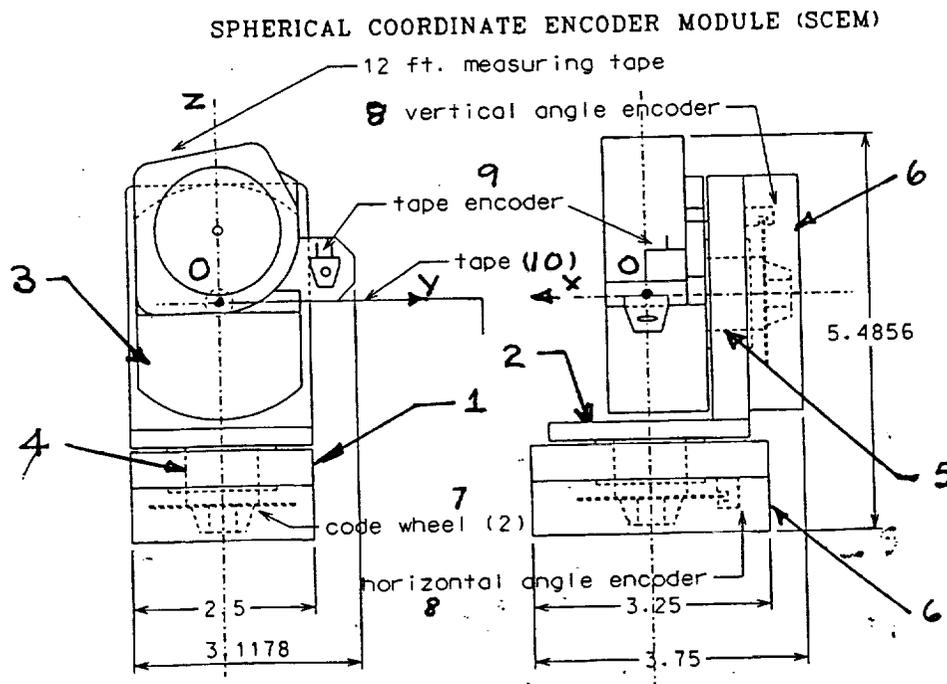


Figure 5. The assembly drawing of SCEM

3.3 TYPICAL EQUATIONS FOR A SUPPORT FROM THE OUTPUT SPHERICAL COORDINATES (R, θ_z, θ) , OF SCFM.

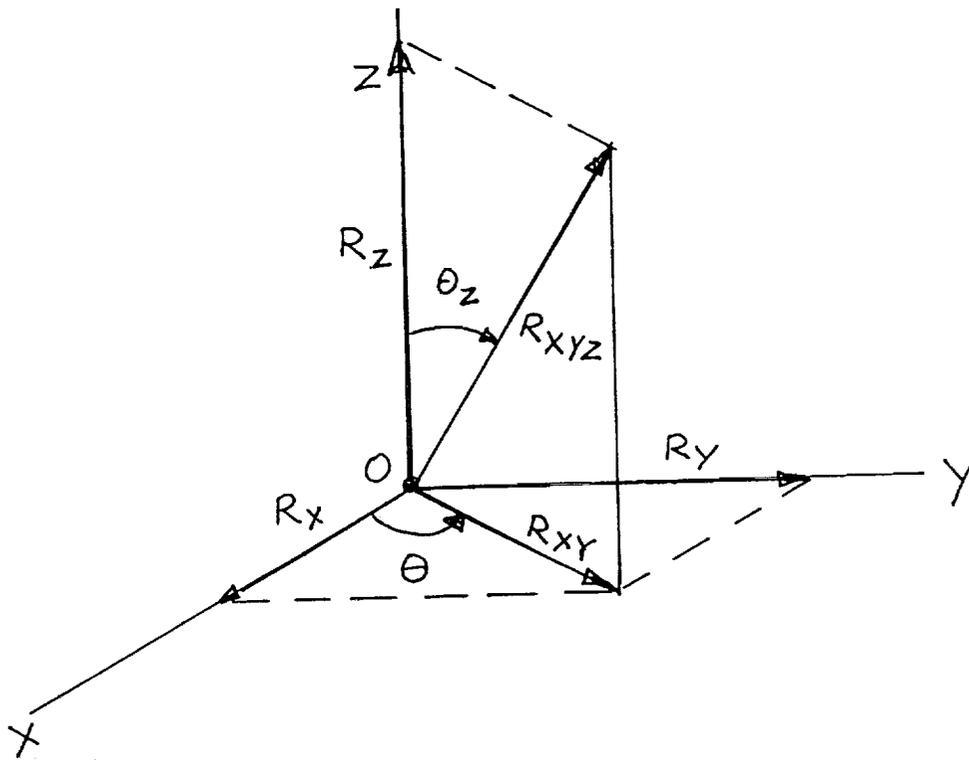


Figure 6. Spherical Coordinates, Space Vector and its components.

$R_{xyz} = |R|$; R_{xyz} is Radius of Space Vector given by the length of the tape.

$$R_{xy} = |R_{xyz} \sin \theta_z| ;$$

θ_z is the angle of R_{xyz} from z axis.
 θ_z is given by the Vertical Code Wheel.

$$R_x = R_{xy} \cos \theta ;$$

θ is the angle of R_{xy} from x axis.
 θ is given by the Horizontal Code Wheel.

$$R_y = R_{xy} \sin \theta$$

$$R_z = R_{xyz} \cos \theta_z$$

The x, y, z coordinates of the supports in the Boom Coordinate System are obtained by applying further transformations, that were discussed in detail in my 1994 NASA/ASEE report available with my NASA Colleague Eduardo Lopez.

4. ALIGNMENT OF RIEE ROTATION AXIS AND RACK INSERTION

Figure 7 below, shows the views of the left and right support points LS and RS with their centerpoint CS and the RIEE rotation axis points LE and RE with their centerpoint CE before and after alignment.

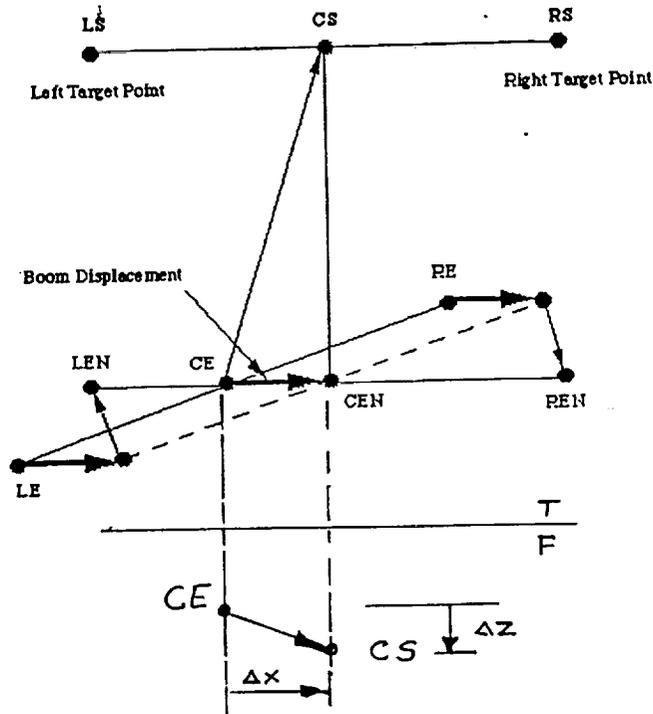


Figure 7. RIEE Rotation Axis Alignment

The following are the steps for the RIEE Alignment and Rack Insertion.

1. The Centers of Module Supports and RIEE Ends are made to have same X and Z coordinates by moving the boom.
2. Ends of RIEE are moved so that the Module Support Axis and RIEE Rotation Axis are Parallel.
3. Check by Repeating Measurements and correct by Repeating 1 & 2.
4. Move the RIEE so that the support and RIEE rotation axes are at proper distance.
5. Rotate the Rack on the RIEE rotation axis, gently into final position.

The above steps were discussed in the 1994 report with typical numerical values.

5. CONCLUSIONS AND RECOMMENDATIONS:

In this report the design of a Spherical Coordinate Encoder Module (SCEM), the equations for the rectangular coordinates of the Supports measured by SCEM, and alignment procedures were discussed. Equations derived in last years report for the alignment will also hold good for alignment with SCEM. The sperical targrts (see Figure 3) suggested last year for the vision system AVAS, can be simplified as Colored Dots.

Both SCEM and AVAS will be useful in a variety of Payload Transfer applications. The author, with 8 years of his US Industry Design and Development Experience is willing to help on the hardware and software Prototype Development projects of these systems.

6. REFERENCES:

A. KSC drawing set # 82K03931 and associated drawings.

B. Narasimha S. Malladi, "RACK INSERTION END-EFFECTOR (RIEE) AUTOMATION", 1993 NASA/ASEE Summer Faculty Report to KSC.